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(54) Thermo Storage Water Heater Having Extended Heat
Withdrawal

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Abstract
THERMO STORAGE WATER HEATER
HAVING EXTENDED HEAT WITHDRAWAL

5 A stored energy heater utilizing one or more tanks
(6, 7) for containing the recirculated liquid storage
medium. Each heater consists of a "master" (16) and
"slave" (18) tank unit. The master incorporates a con-
centric tube heat exchanger (20) for heating system
fluid. Predetermined tank height/diameter ratios,
10 liquid return location and an internal standpipe (52)
with two storage outflow openings (41, 50) establish
control of storage media temperature and heater fluid
"flashing". Storage tank re-circulation rates are
adjusted by system fluid heat requirements.

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THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. In a stored energy heater of the type utilizing periodically heated storage medium and a pumped transfer liquid for transferring heat between storage medium and a heating system liquid, the improvement comprising;

a vertically disposed storage tank having a top and bottom, and a sidewall therebetween for containing the storage medium and liquid and having a height to width ratio in excess of one;

a standpipe, vertically disposed in said tank having an open upper end for withdrawing transfer fluid and a lower end fixed in said tank bottom defining a liquid outlet;

an orifice in said standpipe intermediate said upper end and outlet;

an inlet in said tank sidewall intermediate said orifice and standpipe upper end;

means aperiodically heating the storage medium and transfer liquid to a predetermined temperature;

means circulating the transfer liquid flow through said tank, via said tank inlet, standpipe outlet and orifice, said outlet and orifice apportioning liquid flow through said standpipe open end and orifice in a predetermined ratio;

means cooperating with said circulating means for transferring heat from said circulating storage fluid to the system liquid;

means responsive to said system liquid temperature for varying storage liquid flow established by said circulating means;

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wherein heat extraction from said storage is adjusted by said varying liquid flow to circulate pre-selected portions of stored transfer liquid, thereby providing improved utilization of storage heat.

2. The heater of claim 1 wherein said height to width ratio is essentially 5 to 2.

3. The heater of claim 1 wherein said orifice and standpipe open end are located approximately 5% and 75% of the tank height.

4. A heater for supplying heat to an external water system having electrically heated water for storing heat at a temperature substantially above heated system requirements, without flashing said system comprising;

means electrically heating said storage water;

an external system containing flowing system water;

a vertically disposed storage tank containing storage water, comprising;

upper and lower tank ends having a first principle dimension;

a side wall having a second principle dimension;

a ratio of said sidewall and one end dimensions lying between 1 to 2 and 1 to 4;

means in fluid communication with said system and tank for transferring heat from said storage water to said system water;

means circulating said storage water through said tank and exchange means;

a standpipe in said tank for controlling circulation of storage water therethrough having one end fixed in the lower tank end, comprising;

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an open upper end and a flow sensitive orifice intermediate said upper and lower tank ends for controllably proportioning said storage water circulation therebetween, said orifice and standpipe end in fluid communication with a storage fluid outlet defined by said standpipe lower end;

a storage fluid return in said sidewall in spaced vertical relationship intermediate said orifice and standpipe open end;

means responsive to system water temperature internal said heat transferring means, for controlling said circulating means in accordance with predetermined system temperature, said controlling means varying said proportion by adjusting storage fluid flow between said orifice and standpipe upper end for maximum orifice flow at the highest storage temperature;

whereby storage water is initially transferred from fluid in said storage tank lower portion without flashing said system water.

5. In combination, a water heater having liquid heat storage, a tank for containing said stored liquid at temperatures greater than system water boiling temperature, a heat exchanger, a pump for circulating storage liquid through the exchanger and tank for heating isolated system water, said tank comprising;

a top cover and lower base having a first principle dimension; vertical sidewalls joining said cover and base having a second principle dimension; wherein a ratio of said second to first dimensions is substantially greater than unity;

an essentially vertical standpipe in said tank having an open upper end adjacent said cover and a lower end fixed in said base defining a storage water outlet;

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an orifice defined by said standpipe wherein flow resistance increases substantially as circulation increases, said orifice adjacent said base and in fluid communication with said open end and outlet;

an opening in said sidewall vertically displaced from said orifice for returning circulated storage liquid to said tank, and defining first and second tank liquid circulation zones respectively above and below said opening, whereby storage liquid outflow said zones is selectably controlled by varying said circulating liquid flow;

means, in said exchanger, responsive to system water temperature for increasing storage liquid circulation by said pump in proportion to heating demand;

wherein increasing heat demand apportions storage water flow between said orifice and upper standpipe open end thereby adjusting heat withdrawal from said second zone to said first zone without substantial mixing therebetween, providing storage water outflow at higher temperatures.

6. The heater of claim 5 wherein said temperature responsive means includes an aquastat.

7. The heater of claim 5 wherein said standpipe comprises;

a first conduit including a sidewall having inner and outer surfaces.

8. The heater of claim 7 wherein said orifice further comprises;

an aperture in said standpipe sidewall intersecting said sidewall surfaces and defining inner and outer peripheral edges and annular connecting surface therebetween, and further comprising;

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an entrance orifice defined by said outer edge;

an internal orifice defined by said inner edge,
upwardly displaced along said standpipe inner surface.

9. The heater of claim 8 wherein said connecting surface intersects said conduit sidewall at a 45 degree angle.

10. The heater of claim 7 wherein said orifice comprises;

a second conduit having a first length along a principle axis and an inner diameter;

an intersection of said first and second conduits such that the axes of said first and second conduits intersect at a predetermined angle;

an inflow orifice defined by said intersection and predetermined values of said second conduit inner diameter and length.

11. The orifice of claim 10, wherein the intersecting angle is 45 degrees, the inflow orifice has a diameter of .375 inches, and a length of 1 inch.

12. The heater of claim 5 wherein storage circulation on initial system demand is essentially through said second zone thereby supplying storage water without flashing system water in the heat exchanger.

13. The heater of claim 5 wherein said ratio is 5 to 2.

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THERMO STORAGE WATER HEATER
HAVING EXTENDED HEAT WITHDRAWAL

A hot water heater employing horizontal heat storage tanks and dual immersed heat exchangers for heat extraction has been disclosed.

Reference may be made to U.S. patents 3,422,248,
5 titled "HYDRONIC ELECTRIC HEATING SYSTEMS", and U.S. patent 4,243,871, titled "FLUID HEATING SYSTEM WITH STORAGE OF ELECTRIC HEAT".

BACKGROUND OF THE INVENTION

This invention relates generally to stored energy
10 liquid heaters, employing thermal storage. Heaters of this type have proven advantageous in supplying continuous heat at controlled temperatures to space heating and process application, from heat sources which are aperiodic in nature. A particular application involves the use of
15 electrical energy during "off-peak" periods for "equalizing" utility electric generating capacity, thereby improving overall efficiency of the supplying electrical utility system through load management. The particular configuration of the invention disclosed employs water heated to a
20 temperature above its atmospheric saturation or boiling value thereby providing increased energy storage. Although those skilled in the art will recognize that other storage materials utilizing an intermediate liquid for transferring heat can be substituted for water storage.

Units disclosed in the above mentioned patents function satisfactorily and are in substantial use. However, it has been found that the control systems utilized require at least one thermal mixing valve to achieve controlled heat withdrawal from storage. Also, the above discussed units utilize horizontal storage tanks containing the heat storage medium, typically a liquid such as water.

It has been discovered that a storage tank or container having essentially a vertical orientation or aspect ratio, i.e., wherein its vertical dimension is some multiple greater than one of its diameter, in conjunction with a novel orifice/standpipe flow control, provides increased utilization of the stored energy heat through improved internal storage temperature distribution.

Therefore, the invention disclosed here provides increased heater reliability through elimination of the above mentioned mixing valve, and essentially extends the capability of the heater to supply energy at a predetermined temperature through better utilization of the storage medium.

It is, therefore, an object of this invention to provide a stored energy heater having extended supply capabilities through control of internal mixing and temperature distribution of the storage medium.

It is a further object of this invention to provide automatic adjustment of heat withdrawal through storage medium flow control.

It is a further object of this invention to provide a stored energy heater featuring reduced storage heat losses through improved tank design.

It is a still further object of this invention to provide a stored energy heater which is more economic in construction through reduced piping, weight, and elimination of a thermal mixing valve.

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An additional object of this invention is to provide a standpipe/orifice combination which apportions liquid storage media so as to maintain storage outlet temperature by minimizing mixing with return liquid.

5 SUMMARY OF THE INVENTION

In a preferred embodiment of the invention disclosed a plurality of storage tanks consisting of a single master and one or more slave storage tanks is utilized to store periodically available heat, and supply continuous heat to fluid in a connected system, at a predetermined temperature substantially lower than that of the storage medium. An external dual concentric tube heat exchanger is utilized wherein the higher temperature storage or transfer liquid is circulated through an inner tube, while the system liquid or water flows through an annular space between the inner tube and a concentrically disposed outer tube or conduit. Heat withdrawal from the above mentioned storage tanks is accomplished through the use of a unique stand pipe-orifice combination contained in each tank.

System demand controls the operation of a liquid pump, which on initial reduced flow operation circulates the storage fluid through a lower portion of the tank. Flow of high temperature storage liquid in this mode, is controlled by the stand pipe orifice. The orifice/standpipe combination therefore controls heat extraction, and storage container internal liquid flow patterns so as to essentially confine withdrawal to predetermined portions of the storage tank.

On increased heat demand or long time heat extraction from the lower portion of the heat storage tank, a temperature signal increases the pumping capacity thereby modifying the flow patterns through the standpipe and orifice combination to readjust storage fluid flow so that a major portion of the circulated storage fluid is

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extracted from the extreme upper end of the storage tank.

At this point flow internal of said thermal storage, dictated by the essentially vertical orientation of the tank or container, establishes a virtual "wall of low temperature water" which ascends vertically as heat is extracted, and establishes a thermocline, or temperature interface, between return water and remaining higher temperature water remaining in the storage tank. It has been discovered that liquid mixing, and diffusion under these operating conditions is minimal, resulting in negligible dilution (i.e., temperature reduction) of the remaining storage fluid above the before mentioned vertically ascending wall of water. In this manner heat can be supplied to the system water at a consistently higher temperature than would be available with horizontal tank configurations disclosed by the prior art.

A standpipe/orifice combination is utilized wherein total stored liquid outflow exits a tank at its lower extremity. Storage liquid or water is drawn from a storage tank through the standpipe upper end and an orifice in combination flow. The particular orifice utilized provides preferential withdrawal, particularly at lower withdrawal flow rates, from storage liquid located below the tank return. In this way mixing of higher temperature storage water and lower temperature return water is minimized providing extended storage water outflow over a broader demand range.

Thus the disclosed heater provides extended output at predetermined temperature, through the use of a stand pipe/orifice combination providing load-adjusting flow and temperature control of the storage medium. This discovery further allows operation of the disclosed heater without the use of a temperature sensitive mixing valve utilized in the prior art systems.

In addition, as indicated, slave tanks can be operated in flow parallel, having flow and temperature

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patterns essentially identical to those of the master unit. Assuming pump capacity is adjusted correspondingly, additional "slave" units provide multiples of capacity while maintaining the above essentially improved output characteristics and reliability.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a semi-pictorial elevation/front view of a two unit (one master, one slave) with a portion of the master outer shell removed, showing essential locations of the control panel, external piping, heat exchanger, and the insulation-housing envelope.

Figure 2 is a pictorial semi-schematic of the above mentioned master slave combination showing in pictorial/symbolic/circuit notation essential flow paths, and associated control components.

Figure 3 is a perspective, semi cut-away view of the lower or control portion of a master unit. Particularly disclosed is termination of the concentric tube heat exchanger, system and slave unit connections, and location of a "typical" tank temperature control element. Elements familiar to those skilled in the art and non-essential to the disclosed invention have been omitted in the interest of clarifying the disclosed invention.

Figure 4 is a partial section of the master unit shown on line 4-4 of Figure 1, particularly showing the heat exchanger location and its interconnections to the master storage container. Flow directions are schematically shown.

Figures 5a and 5b are sectional views of the orifice/standpipe combination.

Figures 6a and 6b are sectional views of an alternate orifice/standpipe embodiment.

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DETAILED DESCRIPTION OF THE INVENTION

The following description will describe the invention in connection with a preferred embodiment wherein system or process water is heated by heat initially stored in a tank or container utilizing water as an isolated storage medium. In the disclosed embodiment storage water is heated electrically by immersion elements. However, it is not the intention of this disclosure to limit the invention to this embodiment. On the contrary, it is the intent of this application to contemplate all alternatives and modifications such as utilizing heat from external high temperature liquids transferred to the storage medium through immersion heat exchangers, from other heat sources such as high temperature gases. The disclosure and claims is also intended to cover other alternatives, modifications and equivalences may be included within the spirit and scope of the invention, and defined by the appended claims.

Turning first to Figures 1, 2 and 3, a master module 1 and slave module 2 are shown piped so as to provide essentially parallel flow of an isolated liquid storage medium hereinafter described as storage water contained in master tank 6 and slave tank 7 through said tanks. Electrical immersion heating elements 60 and 61 are located adjacent to the bottom of the tanks 6 and 7, as shown. Standpipes 53 and 54 are contained in the respective tanks and each has an open end 50, 51 and lower orifice 41 and 42, respectively arranged to be below the upper level of tank storage water at all times.

It should be noted that as the slave module 2 is from the storage point of view essentially identical to the master module 1, corresponding elements are disclosed. However, except when the slave module departs from operation of the master, the following discussion will be essentially concerned with a single unit, i.e., that employing only the master module storage. Those skilled in the art will readily understand that

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heat withdrawal from the parallel connection of slave and master as disclosed through opening connecting valves 69, will proceed in a manner identical to that of the master alone.

5 As further disclosed in Figures 3 and 4, an essentially circular concentric tube heat exchanger assembly 20 is disposed coaxial to the lower extremity of the tank 6. A pump 25 provides circulation of the storage water via exit 40 and inlet 35 of the tank. The concentric tube heat exchanger provides a flow passage or conduit 22 internal of an outer conduit 21. This arrangement provides an annular flow space 23. As piped, (ref. Figure 2), the pump 25 circulates heated water drawn from the tank 6 via the standpipe 52 through both the upper end 50 and the orifice 41 as will be further discussed.

As shown in Figures 5a, 5b, and Figure 6a and 6b, two forms of outflow orifice 41 or 41a can be utilized. In the preferred embodiment shown on Figure 5a short length of conduit, or pipe "spud" 41b is shown intersecting the standpipe 53. The intersection angle of the conduit 41b is arranged to preferentially supply heated storage water from the lower portion 65 of the storage tank 6. In the alternate embodiment (reference 6a, 6b), an orifice 41a is shown. As disclosed, the intersection of the 41a orifice and standpipe 53 defines inlet and outlet control apertures 41c and 41d. In operation, these act to direct inflow so as to withdraw water from the lower tank portion for an initial pump volume.

30 The high temperature heat source fluid, in this case water, exits the tank at 40, passes through the inner heat exchange conduit 22, the pump 25 and is returned to the tank via inlet 35. System water enters the annular flow space 23 (ref. Figure 4) via inlet 5, and exits at the outlet 55, returning to the system via flow path 15.

35 A temperature sensitive element 52 has its sensing portion immersed in the storage water at a predetermined

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location, which essentially divides the storage tank into a mix portion 65, and a stratified portion 70. Other control elements such as a master storage heat exchanger outlet temperature control 31, a storage pressure relief valve 30, and a drain valve 11 provide
5 required control and access of the heating fluid/storage in master module 1. As indicated in Figure 2, a two unit embodiment employing a master module 1 and slave module 2 is arranged to have parallel flow from the pump
10 25 via interconnecting conduits 32 and 10, allowing extraction of heated storage liquid contained in the slave tank 7 via the standpipe/orifice combination 51, 54 and 42 as discussed above.

An electrical control panel assembly 75 is shown
15 attached to the outer shell 16. No details are provided as the panel is not a part of the invention. The panel supplies electrical energy to heating elements 60 during designated "off peaks" periods through the use of conventional electrical contactors. Maximum heat input is
20 controlled by tank temperature controls 52 and 52a, providing power cutoff when a storage temperature of 280°F is attained. Additional over temperature protection is provided by master and slave storage pressure relief valves 30 and 29 respectively. A pressure/temperature
25 gage 8 is provided for monitoring tank storage conditions.

In operation, system water initially entering the annular flow space 23 of the concentric tube exchanger
20 enters at 5, passes through the annular space 23, and exits at heat exchange outlet 55. When system water
30 reaches a predetermined temperature, thus reducing the temperature of the aquastat or temperature sensitive switch 56 operation of the pump 25 is initiated. Heated storage water is then circulated via the inner
35 heat exchanger tube 22, hot water exit 40, and tank return 35 to heat system water. At this point flow through the tank 6 is predominantly limited

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to the lower or mix area 65, entering the standpipe 52 via the orifice 41 and the upper end 50 in a ratio typically 4/1.

When the heat storage capacity contained in the tank portion 65 is exhausted, exiting system water will further reduce the temperature detected by the aquastat 56, thereby increasing the pump 25 output to a substantially greater value. Due to the characteristics of the orifice 41, additional storage water will enter the standpipe 52, via the upper end 50. As distinguished over the prior art systems, the particular aspect ratio of the storage tank 6 provides a reservoir of stratified water 70 above the mix section 65 at a substantially higher temperature. This action arises from the discovery that during initial heat extraction or draw via inlet 35 and orifice 41 very little diffusion or mixing occurs between tank storage liquid portions 65 and 70. Thus, it has been discovered that with the pump 25 operating at a high pumping rate, cold water returning via inlet 35, due to its higher density, essentially drops to the bottom of the tank 6, establishing a vertically moving wall of water having a thermocline separation or interface. The configuration disclosed essentially minimizes thermal interaction at the thermocline with the vertically moving interface providing exit temperatures at standpipe outlet 50, which are substantially higher due to the absence of mixing, than would be encountered with a tank having identical withdrawal means in essentially a horizontal plane.

This discovery has resulted in utilizing what has normally been considered a disadvantage, i.e., stratification due to differences in density between cold and hot storage water, to extend or sustain the delivered temperature of the storage water. This extension is primarily due to the piston like action of the above mentioned vertically moving interface. Extended withdrawal at a higher temperature results in improved

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utilization of remaining stored heat due to its increased energy or available heat. As shown on Figure 2, a slave module 2 incorporating identical elements of the master module 1 and the utilizing a pump-heat exchanger in common, results in combination having essentially doubled heat capacity. Obviously, those skilled in the art will realize that allowing for increased pumping requirements, a plurality of slave tanks could be utilized. Thus, the disclosed heater is also modular in nature, allowing economical capacity adjustment to particular load requirements.

The particular aspect ratio of the storage tank disclosed also provides a solution to the "flashing" phenomena disclosed in the earlier mentioned prior art. It has been discovered that the disclosed location of tank inlet 35, storage water orifice 41, and immersion elements 61, result in initial withdrawal of the heated storage water at a temperature and flow rate, substantially below that of the stratified tank. Therefore, difficulties due to flashing of the external system water in the area internal of heat exchanger 20 at location 55, where heated system water exits and high temperatures storage water from storage via tank exit 40 enters the heat exchanger 20 have a minimum temperature difference, are prevented. Continued flow through orifice 41 results in moderating storage water temperature through mixing in the low zone 65, further eliminating flashing of the heated system water, which would most likely occur at exit 55 of the heat exchanger 20 as described above.

It should be noted that prior art systems require the use of a substantially unreliable, and relatively expensive mixing valve to eliminate flashing when storage tank orientation was essentially horizontal.

Thus, it is once again apparent that the invention disclosed here has utilized a heretofore considered undesirable condition, i.e., storage tank temperature stratification, in a novel and unobvious way to enhance

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and simplify the performance of a periodically charged
stored energy heater.

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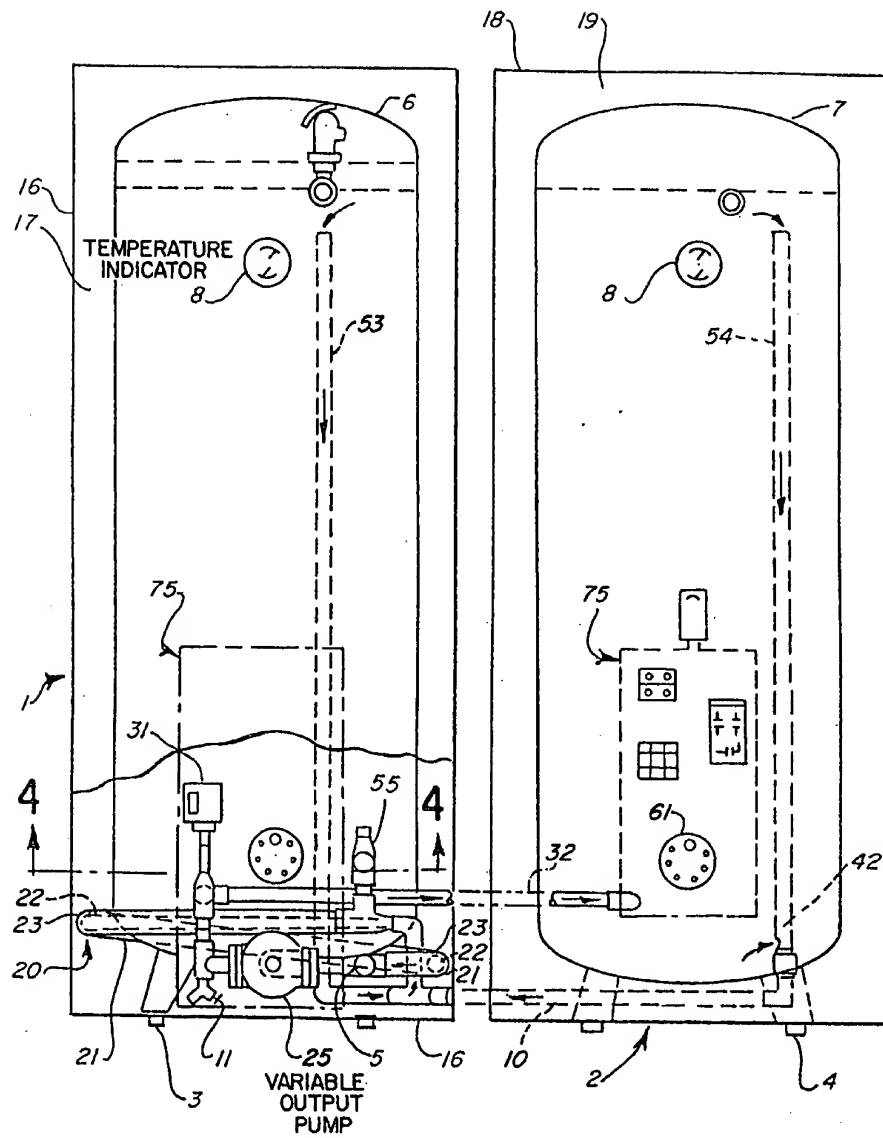


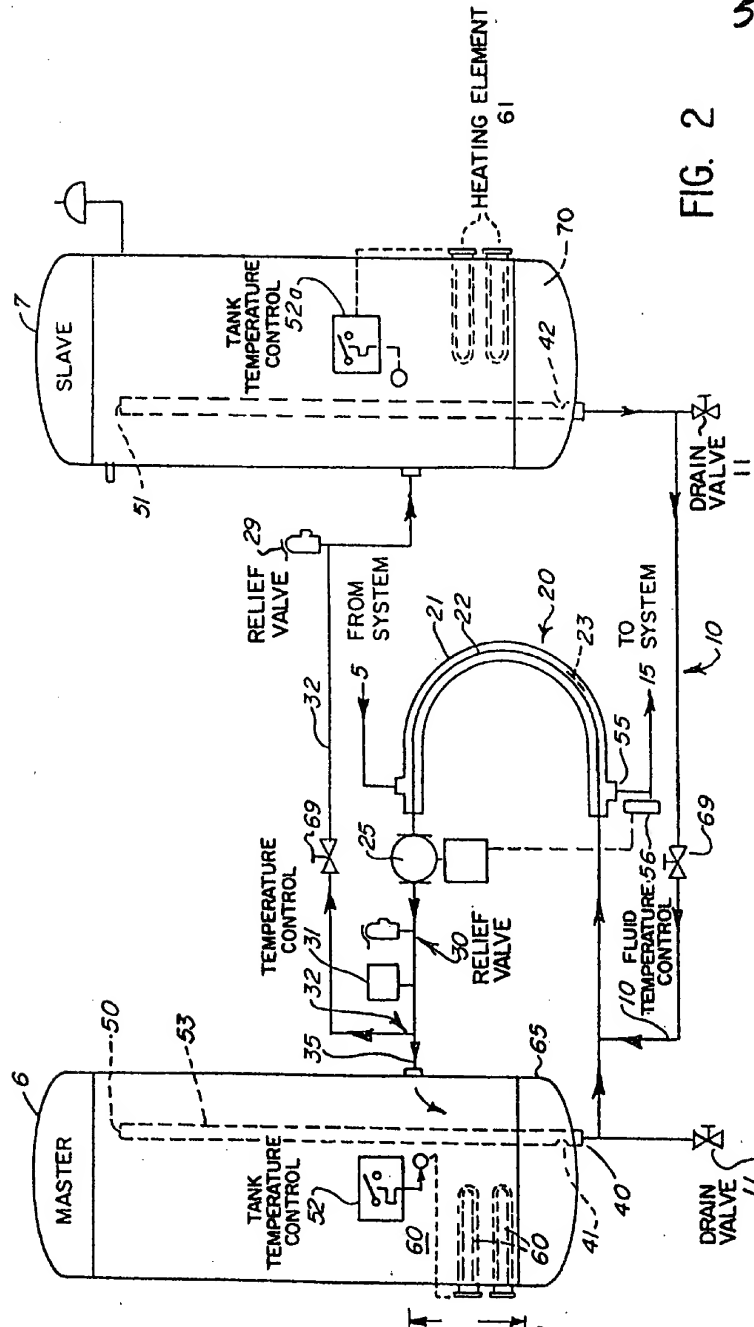
FIG 1

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FIG. 2



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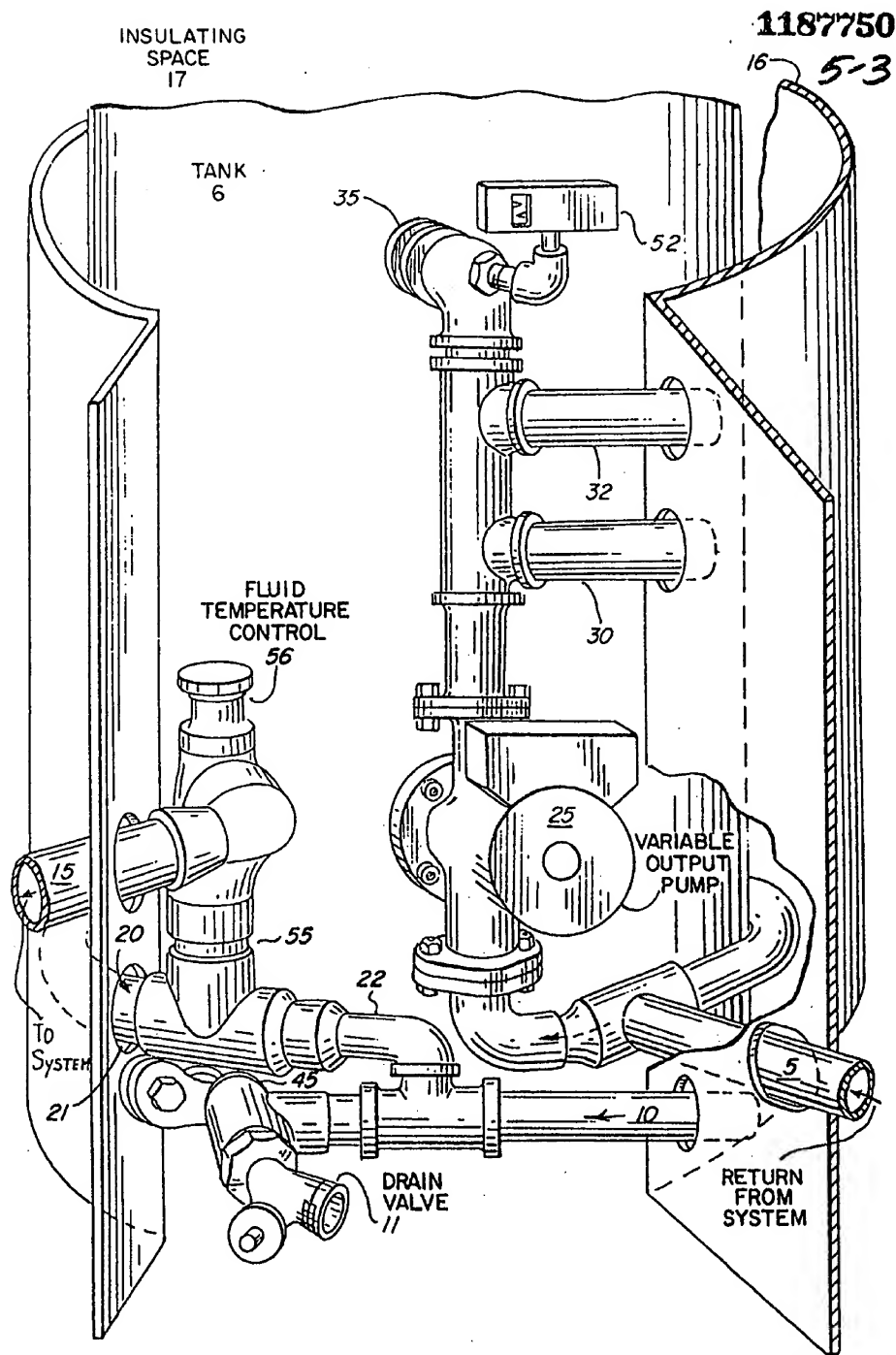


FIG 3

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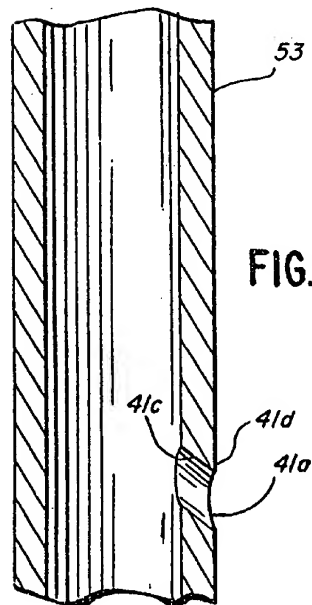
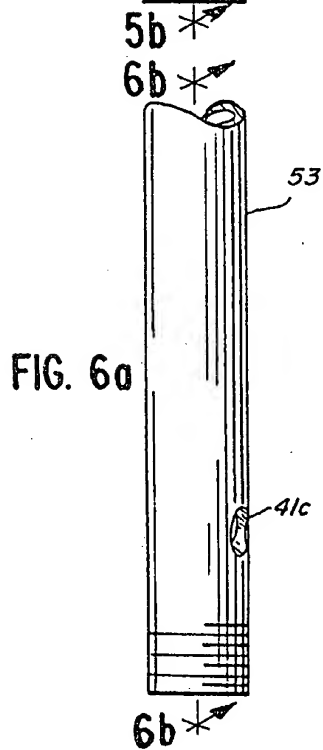
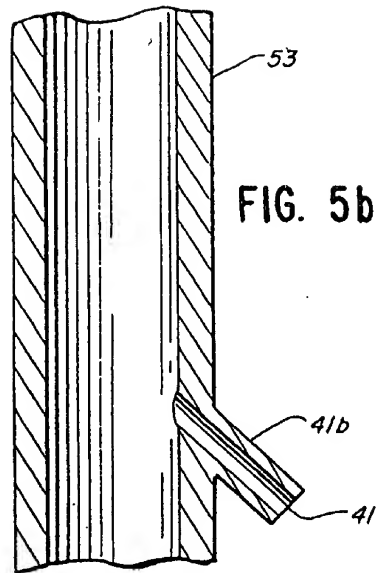
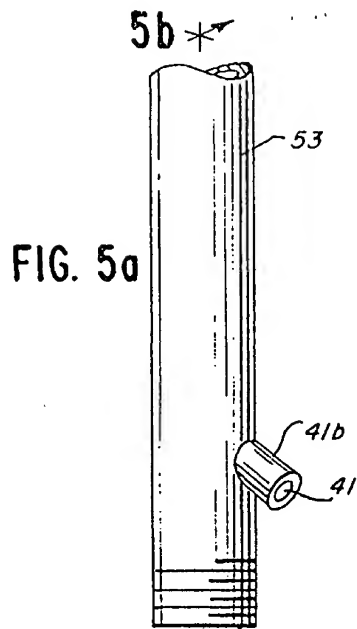
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